Status of BTeV

Joel Butler, Fermilab

URA Visiting Committee

March 15, 2003

Outline

- Review: BTeV Physics Goals and Reach
- The BTeV Detector and R&D Program
- BTeV Cost Estimate, Budgets and Schedule

BTeV

Origins: ■ Fnal FT ■ CLEO ■ Hera/HeraB

Massive expertise in pixels, trigger, electronics, tracking, crystal calorimetery, RICH, & Muon detection

Belarussian State- D .Drobychev, A. Lobko, A. Lopatrik, R. Zouversky

UC Davis - P. Yager

Univ. of Colorado- J. Cumalat, P. Rankin, K. Stenson

Fermi National Lab
J. Appel, E. Barsotti, C. N. Brown , J. Butler, H. Cheung, D. Christian, S. Cihangir, I. Gaines, P. Garbincius, L. Garren, E. Gottschalk, G. Jackson, A. Hahn, P. Kasper, P. Kasper, R. Kutschke, S. Kwan, P. Lebrun, P. McBride, J. Slaughter, M. Votava, M. Wang, J. Yarba

Univ. of Florida at Gainesville
P. Avery

University of Houston
A. Daniel, K. Lau, M. Ispiryan, B. W. Mayes, V. Rodriguez, S. Subramania, G. Xu

Illinois Institute of Technology
R. A. Burnstein, D. M. Kaplan, L. M. Lederman, H. A. Rubin, C. White

Univ. of Illinois- M. Haney, D. Kim, M. Selen, V. Simaitis, J. Wiss

Univ. of Insubria in Como-
P. Ratcliffe, M. Rovere

INFN - Frascati- M. Bertani, L. Benussi, S. Bianco, M. Caponero, F. Fabbri, F. Felli, M. Giardoni, A. La Monaca, E. Pace, M. Pallotta, A. Paolozzi

INFN - Milano - G. Alimonti, L. Edera, D. Lunesu, S. Magni, D. Menasce, L. Moroni, D. Pedrini, S.Sala, L. Uplegger

INFN - Pavia- G. Boca, G. Cosssali, G. Liguori, F.Manfredi, M. Manghisoni, M. Marengo, L. Ratti, V. Re, M. Santini, V. Speziali, P. Torre, G. Traversi

IHEP Protvino, Russia
A. Derevschikov, Y. Goncharenko, V. Khodyrev, V. Kravtsov, A. Meschanin, V. Mochalov, D. Morozov, L. Nogach,

K. Shestermanov, L. Soloviev, A. Uzunian, A. Vasiliev

University of Iowa
C. Newsom, & R. Braunger

University of Minnesota
J. Hietala, Y. Kubota, B. Lang, R. Poling, & A. Smith

Nanjing Univ. (China)-
T. Y. Chen, D. Gao, S. Du, M. Qi, B. P. Zhang, Z. Xi Zhang, J. W. Zhao

Ohio State University-
K. Honscheid, & H. Kagan

Univ. of Pennsylvania
W. Selove

Univ. of Puerto Rico
A. Lopez, & W. Xiong

Univ. of Science & Tech. of China - G. Datao, L. Hao, Ge Jin, T. Yang, & X. Q. Yu

Shandong Univ. (China)-
C. F. Feng, Yu Fu, Mao He, J. Y. Li, L. Xue, N. Zhang, & X. Y. Zhang

**Southern Methodist Univ - ** T. Coan, M. Hosack

SUNY Albany - M. Alam

Syracuse University
M. Artuso, S. Blusk, J. Butt, C. Boulahouache, O. Dorjkhaidav J. Haynes, N. Menaa, R. Mountain, N.Nadakumar, L. Redjimi, R. Sia, T. Skwarnicki, S. Stone, J. C. Wang, K. Zhang

Univ. of Tennessee -
T. Handler, R. Mitchell

Vanderbilt University -
W. Johns, P. Sheldon, E. Vaandering, & M. Webster

Univ. of Virginia: M. Arenton, S. Conetti, B. Cox, A. Ledovskoy, H. Powell, M. Ronquest, D. Smith, B. Stephens, Z. Zhe

Wayne State University
G. Bonvicini, D. Cinabro, A. Shreiner

University of Wisconsin
M. Sheaff

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York University - S. Menary

There has been dramatic and exciting progress recently in the Study of CP Violation

- KTeV and NA48 have established direct CP violation in K decays

- BaBar and Belle have conclusively established CP violation in B decays through their measurement of values of sin 2β that are many σ from zero. They will continue to pursue CP violation in B decays in B_d and B_u for many years, eventually limited by the number of B's PEP II and KEK can make

- Fermilab: Run II is expected to bring new results on B_s mixing and CP violation studies in a variety of $B_{d/u}$ and B_s final states from CDF and D0

After this phase, there will still be much work to be done and that is where BTeV will excel!

Wolfenstein Parameterization of the CKM Matrix

The CKM Matrix describes the mixing of the charge 1/3 quarks, here to 3rd order in λ for real part and 5th order in imaginary part

$$\begin{pmatrix} 1-\frac{1}{2}\lambda^2 & \lambda & A\lambda^3\left(\rho - i\eta\left\{1-\frac{1}{2}\lambda^2\right\}\right) \\ -\lambda & 1-\frac{1}{2}\lambda^2 - i\eta A^2\lambda^4 & A\lambda^2\left(1+i\eta\lambda^2\right) \\ A\lambda^3\left(1-\rho-i\eta\right) & -A\lambda^2 & 1 \end{pmatrix}$$

η is the imaginary piece of the CKM elements V_{td} and V_{ub}.
According to the SM, η is responsible for CP violation, in both Kaon and B (and all other) decays. The smallest number of generations for which unitarity permits a weak phase is three generations.

Is this description right? Is it complete? Physics beyond the Standard Model could cause deviations from this picture.

The CPV Situation

- **The Standard Model of CPV is <u>unique, predictive, and testable. Once the CKM matrix parameters are pinned down, all CP violating decays are in principle determined (modulo hadronic uncertainties)</u>**
- **CPV is, even now, one of the <u>LEAST TESTED</u> aspects of the Standard Model**
- **Almost any <u>EXTENSION</u> of the Standard Model <u>has new sources of CPV</u>**
- **The observed <u>baryon asymmetry of the universe requires new sources of CPV</u> (not necessarily at this scale, though)**

It is highly likely that the SM picture of CPV is incomplete.
CPV and rare B decays are an excellent probes for new physics.

Conclusion: We should challenge the SM picture of CPV and rare decays on every front!

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New Physics Opportunities
# (in the loops and boxes)

- Generic tests -- Look for inconsistencies in SM predictions, e.g.:

$$\sin \chi = \frac{|V_{us}|^2}{|V_{ud}|} \times \frac{\sin \beta \sin \gamma}{\sin(\beta + \gamma)}$$

- Specific Models
  - SUSY: MSSM and others
  - Higgs: SUSY, General Multi-Higgs
- Left-Right symmetric models
- Extra Down singlet quarks
- FCNC Couplings of the Z Boson
- Non-Commutative Geometries
- Extra Dimensions

Note that when new physics begins to emerge from the Tevatron or CMS and ATLAS, it will have definite implications for rare decays and CP violation of Bottom and charm. Studies from BTeV can shed light on the nature of the new phenomena.
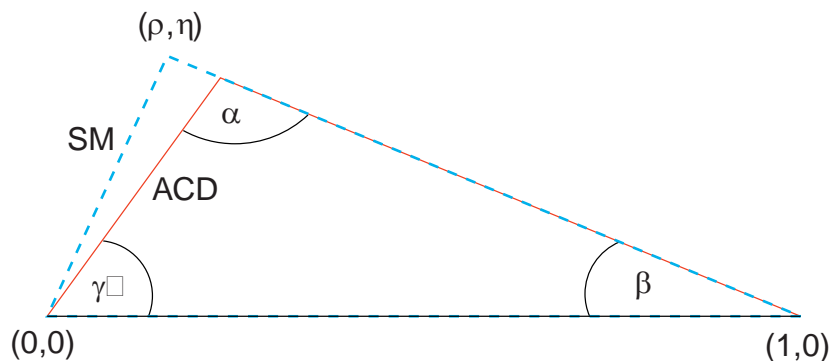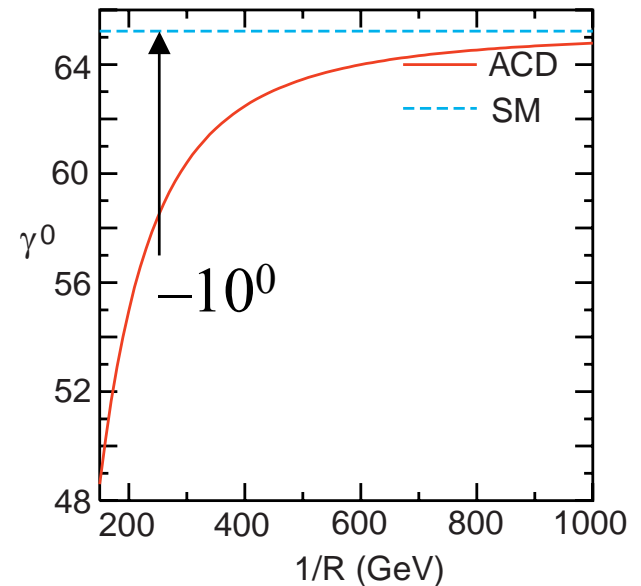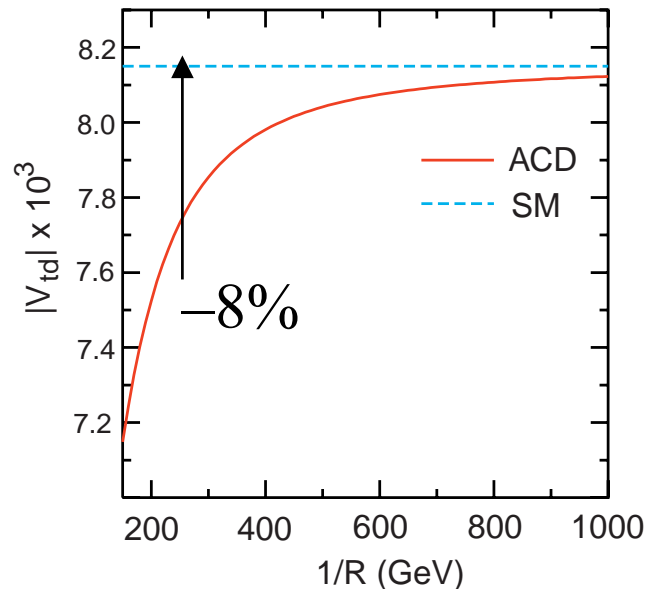
Key Measurements of the CKM matrix in B Decays
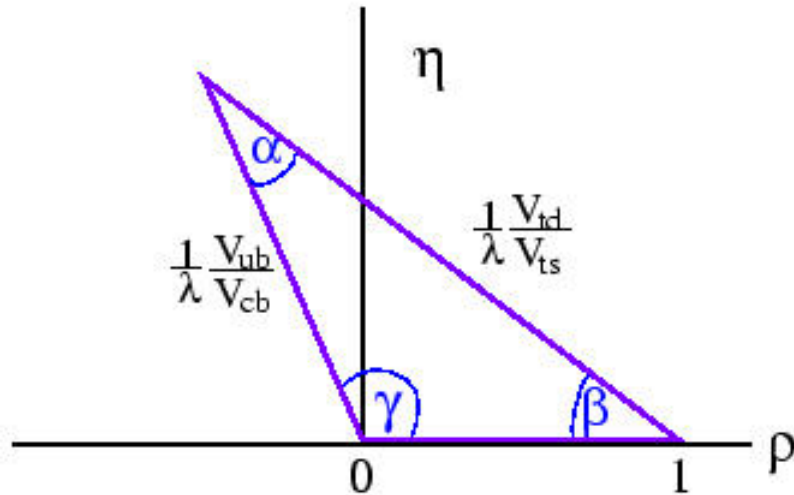
$$\chi = \arg\left(-\frac{V_{cs}^* V_{cb}}{V_{ts}^* V_{tb}}\right)$$

Physics Quantity	Decay Mode
$\sin(2\alpha)$	$B^o \to \rho\pi \to \pi^+\pi^-\pi^o$
$\cos(2\alpha)$	$B^o \to \rho\pi \to \pi^+\pi^-\pi^o$
$\text{sign}(\sin(2\alpha))$	$B^o \to \rho\pi, B^o \to \pi^+\pi^-$
$\sin(\gamma)$	$B_s \to D_s K^-$
$\sin(\gamma)$	$B^+ \to D^o K^+$
$\sin(\gamma)$	$B \to K\pi$
$\sin(\gamma)$	$B \to \pi^+\pi^-, B_s \to K^+K^-$
$\sin(2\chi)$	$B_s \to J/\psi\eta', J/\psi\eta$
$\sin(2\beta)$	$B^o \to J/\psi K_s$
$\sin(2\beta)$	$B^o \to \phi K_s, \eta' K_s, J/\psi\phi$
$\cos(2\beta)$	$B^o \to J/\psi K^*, B_s \to J/\psi\phi$
x_s	$B_s \to D_s\pi^-$
$\Delta\Gamma$ for B_s	$B_s \to J/\psi\eta', K^+K^-, D_s\pi^-$

About 1/2 of the key measurements are in B$_s$ decays!
About 1/2 of the key measurements have π^o's or γ's in the final state! BTeV addresses these issues.

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One Extra Dimension

- Precision measurements needed for large 1/R

Physics Reach in 10^7 s (CPV)

Reaction	$\mathcal{B}$ (B)(x10^{-6})	# of Events	S/B	Parameter	Error or (Value)
$B^o \to \pi^+\pi^-$	4.5	14,600	3	Asymmetry	0.030
$B_s \to D_s K^-$	300	7500	7	γ	8º
$B^o \to J/\psi\, K_S$ $J/\psi \to \ell^+\ell^-$	445	168,000	10	$\sin(2\beta)$	0.017
$B_s \to D_s \pi^-$	3000	59,000	3	x_s	(75)
$B^- \to D^o(K^+\pi^-)K^-$	0.17	170	1		
$B^- \to D^o(K^+K^-)K^-$	1.1	1,000	>10	γ	13º
$B^- \to K_S \pi^-$	12.1	4,600	1		<4º +
$B^o \to K^+\pi^-$	18.8	62,100	20	γ	theory errors
$B^o \to \rho^+\pi^-$	28	5,400	4.1		
$B^o \to \rho^o\pi^o$	5	780	0.3	α	~4º
$B_s \to J/\psi\, \eta$,	330	2,800	15		
$B_s \to J/\psi\, \eta'$	670	9,800	30	$\sin(2\chi)$	0.024

$J/\psi \to \ell^+\ell$

BTeV "Recent" Chronology

- **June 2000 -- BTeV received unanimous Stage I approval at Fermilab after an incredibly rigorous proposal and cost evaluation process**
- **BTeV was not proposed for funding by DOE in 2001 or 2002 and no decision process was provided**
- **Discussion between M. Witherell, P. Rosen, and BTeV resulted in descoping proposal and path we are now following with promise of a decision this fall based on review by P5**
- **April 2002 -- Rescoped "single arm" BTeV received unanimous "reaffirmation" by PAC (several new members) who considered science, competitiveness, fit to lab program/budget, interference with Run II, MINOS, MiniBoone, and Linear Collider R&D and provided specific prioritization for the effort**
- **October 2002, review by Fermilab Office of Construction Management (Templ review) resulted in only minor changes to cost estimate**
- **Preparing for review by P5, March 26, 27 2003.**

The Re-scoped Version of BTeV 's Stage I approval was reconfirmed , unanimously, by the FNAL PAC in May 2002. Mike Witherell described BTEV as an "ideal" B physics experiment at the FNAL User's Meeting last year [11]

Key Design Features of BTeV

- ◆ **A dipole located ON the IR gives BTeV a spectrometer covering the forward antiproton rapidity region.**

- ◆ A precision vertex detector based on **planar pixel arrays**

- ◆ A **vertex trigger at Level I** which makes BTeV especially efficient for states that have only hadrons. The tracking system design has to be tied closely to the trigger design to achieve this.

- ◆ Strong particle identification based on a **Ring Imaging Cerenkov counter.** Many states emerge from background only if this capability exists. It enables use of charged kaon tagging.

- ◆ **A lead tungstate electromagnetic calorimeter for photon and π^0 reconstruction.**

- ◆ A very **high capacity data acquisition system** which frees us from making excessively restrictive choices at the trigger level

Work Breakdown Structure

BTeV Detector Layout
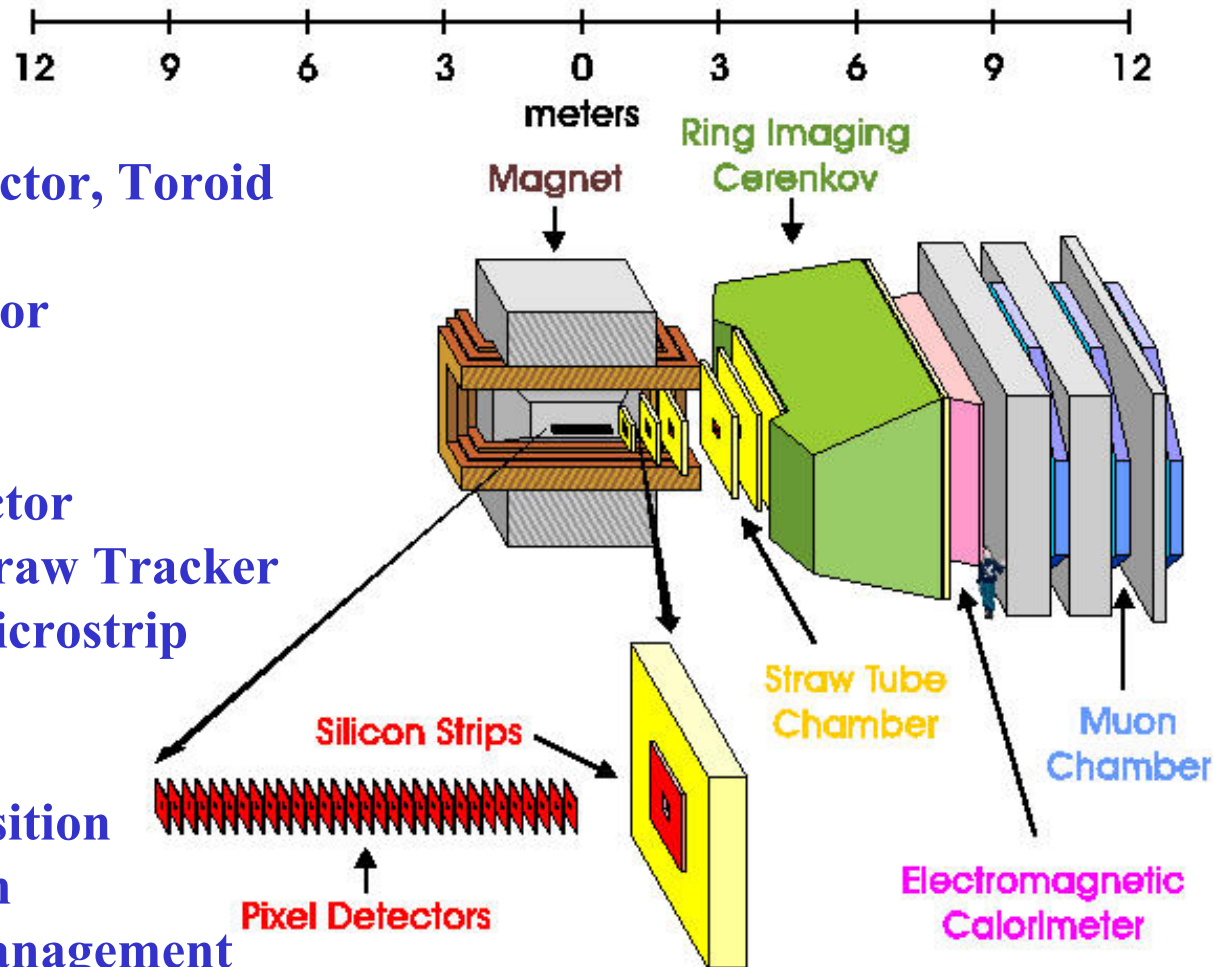
1.1 Vertex Detector, Toroid and Beam Pipe
1.2 Pixel Detector
1.3 RICH
1.4 EMCAL
1.5 Muon Detector
1.6 Forward Straw Tracker
1.7 Forward Microstrip tracker
1.8 Trigger
1.9 Data Acquisition
1.10 Integration
1.11 Project Management

Experiment R&D

- The creation of a new experiment is now almost always a big task, involving significant R&D.
  - For BTeV, this meant developing new kinds of detectors and triggers to cope with the challenging environment of the Tevatron

The development of a sophisticated new experiment and the demonstration of its technical and scientific feasibility is in itself a significant research project and needs support, staffing, supervision, review, and *recognition*.

We have had a very efficient, successful R&D program which has or will soon demonstrate all the key detector, trigger and data acquisition techniques. It has received crucial support from FNAL, the DOE University Program, the NSF, INFN (Italy) and IHEP (Russia)

BTeV R&D Highlights and Plans

- **Pixel Detector: achieved design (5-10 micron) resolution in 1999 FNAL test beam run. Demonstrated radiation hardness in exposures at IUCF. The final sensor and readout chip has been bench tested and will undergo final testing in FNAL test-beam in 2003**

- **Straw Detector: prototype built, to be tested at FNAL in 2003**

- **EMCAL: four runs at IHEP/Protvino demonstrated resolution and radiation hardness,and effectiveness of calibration system. A fifth test will occur in April.**

- **RICH: HPD developed and is being bench tested. FE electronics prototype developed for HPD's. FE electronics for MAPMT option being developed Full test cell under development for beam test at FNAL in 2003**

- **Muon system tested in 1999 FNAL test beam run. Better shielding from noise implemented and bench-tested. Design to be finalized in FNAL test- beam in 2003**

- **Silicon strip electrical and mechanical design well underway**

- **Trigger code implemented on FPGA, Prototypes being constructed. NSF/RTES proposal approved to write fault tolerant software for massively parallel systems**

Technical Status

- Out basic **design has been stable** since the original proposal in May 2000.

- We have a highly efficient, lean and mean, R&D program which is succeeding on all fronts

- The major issue over which we were unsure is now resolved: **we will not use an aerogel radiator but a liquid radiator** for the low momentum particle ID

- **We have eliminated three major criticisms:**
  - We will use commercial networking equipment in the DAQ rather than building a custom switch
  - We have received through the NSF, the funding required to develop a fault-tolerant, fault-adaptive, software system for the trigger farm
  - We have eliminated liquid in favor of thermopyrolitic graphite to conduct heat away from the pixel detector

- **No "gotcha"s. Many "plans" in 2000 are well on their way to realization today. A few choices among workable options still to be made.**

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Pixel Vertex Detector

Reasons for Pixel Detector:

- Superior signal to noise
- Excellent spatial resolution -- 5-10 microns depending on angle, etc
- Very low occupancy
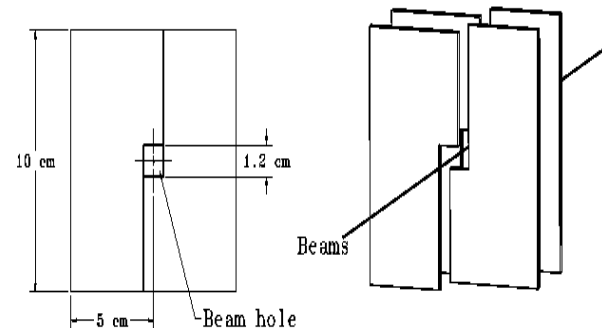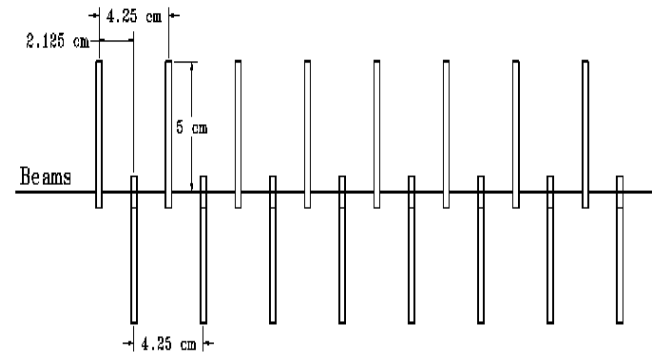- Very fast
- Radiation hard

Special features:

- It is used directly in the Level 1 trigger
- Pulse height is measured on every channel with a 3 bit FADC
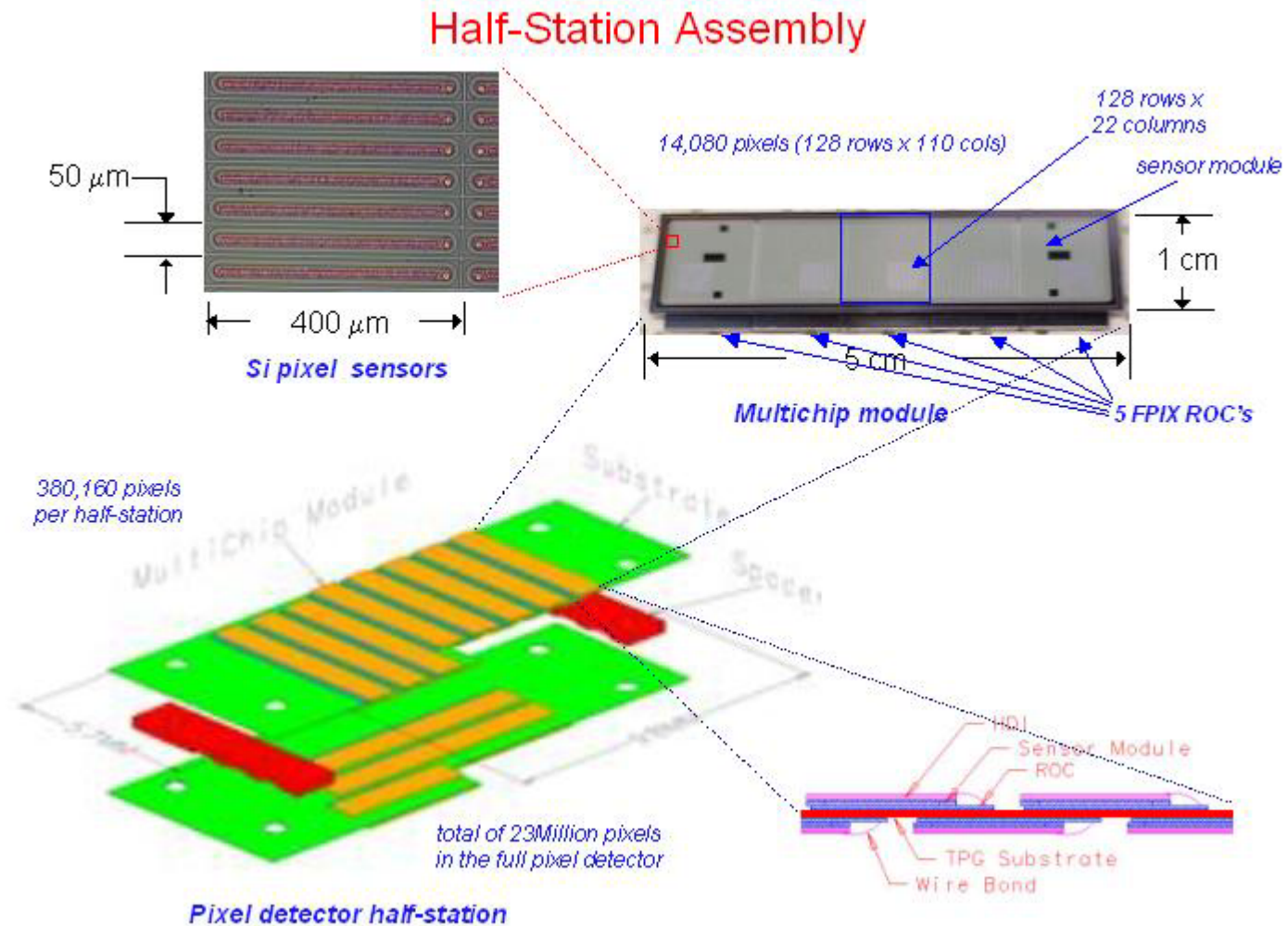- It is inside a dipole and gives a crude standalone momentum

The BTeV Baseline Pixel Detector

400μ
50μ
4mm
5c

Pixel Orier

4.25 cm
2.125 cm
5 cm
Beams
4.25 cm

10 cm
1.2 cm
Beams
5 cm
Beam hole

Readout Chip

Half-Station Assembly

50 μm

400 μm

Si pixel sensors

14,080 pixels (128 rows x 110 cols)

128 rows x 22 columns

sensor module

1 cm

5 cm

Multichip module

5 FPIX ROC's

380,160 pixels per half-station

total of 23Million pixels in the full pixel detector

Pixel detector half-station

HDI
Sensor Module
ROC
TPG Substrate
Wire Bond

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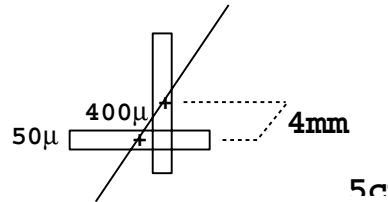
Vacuum System/Resolution
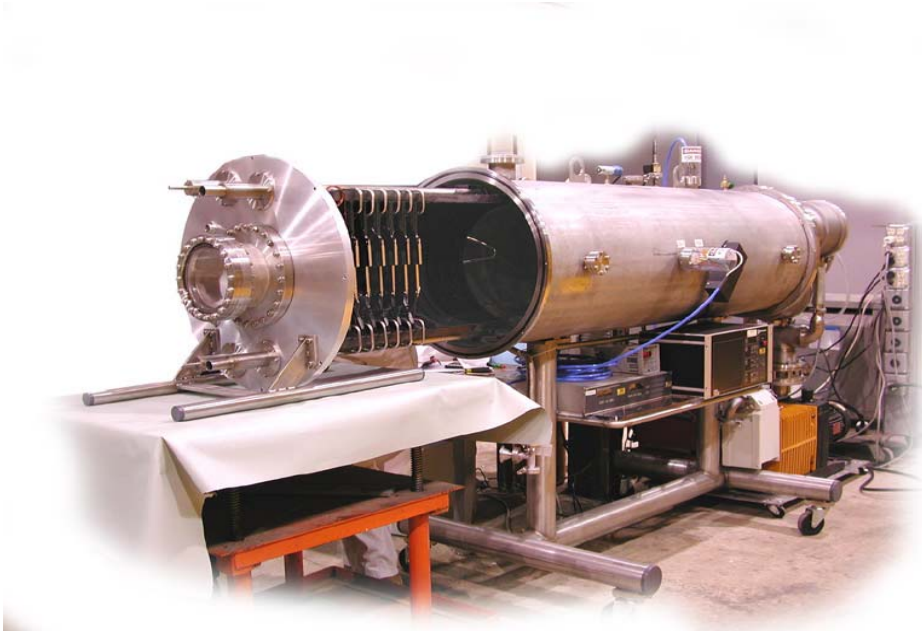
Fig. 4: Photo of the prototype of the vacuum system for the silicon pixel detector
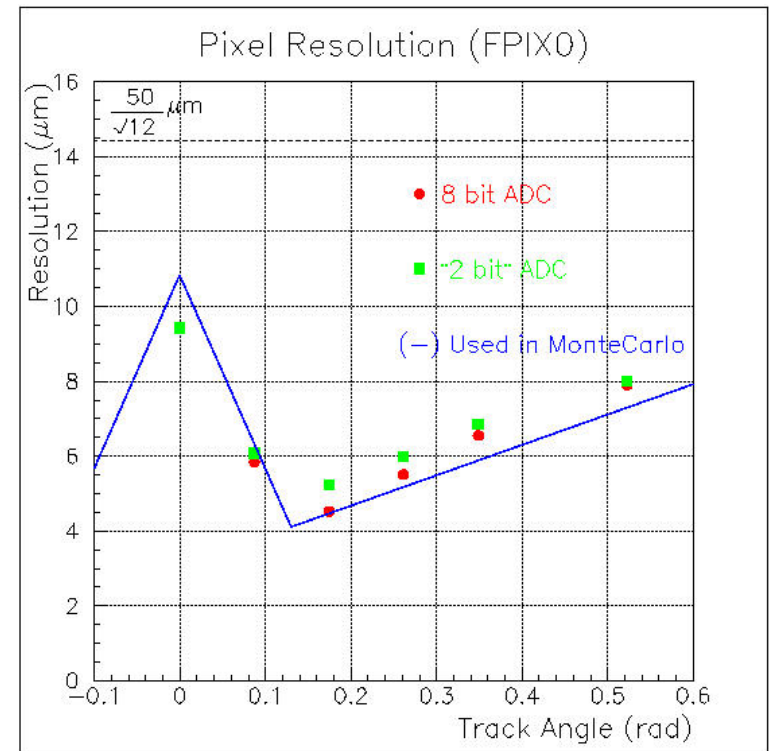
Forward Tracker

Table 4.4: Properties of the baseline forward straw tracker (1 arm)

Property	Value
Straw size	4 mm diameter
Central hole	27 cm × 27 cm
Total Stations	7
Z positions (cm)	95, 138, 196, 288, 332, 382, 725
Half size (cm)	27, 41, 61, 88, 102, 116, 204
Views per station	3 (X,U,V)
Layers per view	3
Total number of straws	29,088
Total station thickness	0.6% X_0
Total channels	58,176
Readout	ASD + timing chip (6 bits), sparsified

4mm Straws at Large angles (low occupancy)

Table 4.5: Properties of the baseline forward silicon tracker (1 arm)

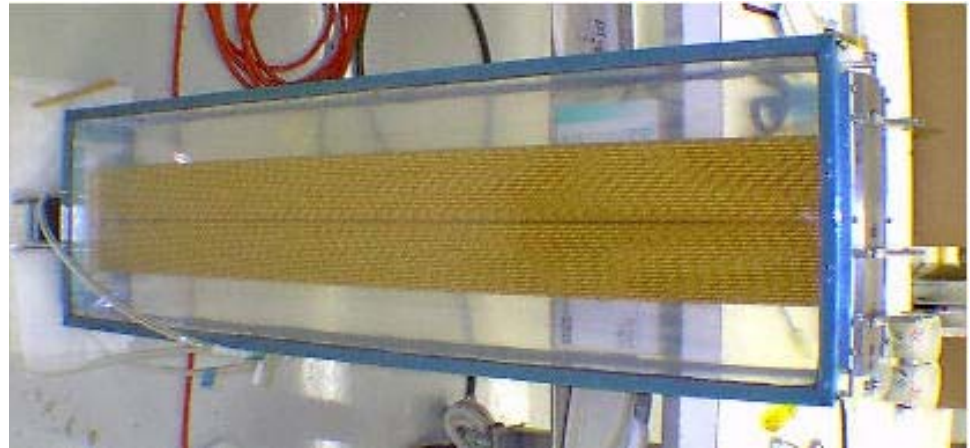| Property	Value
Si-sensors	~ 7 × 7 cm^2, p-on-n type
Pitch	100 μm
Thickness	200 μm
Sensor configuration	4 ladders of 4 sensors
Coverage	27cm × 27cm
Central hole	5.4 cm × 5.4 cm (7 cm × 7 cm in last station)
Total stations	7
Z positions (cm)	99, 142, 200, 292, 336, 386, 729
Views per station	3 (X, U, V)
Channels per view	~5,600
Total channels	~127,600
Readout	sparsified binary

100μ Strips at small angles (high occupancy)

Forward Tracker

Prototype Straw tracker being constructed for FNAL beam test summer/fall 2002
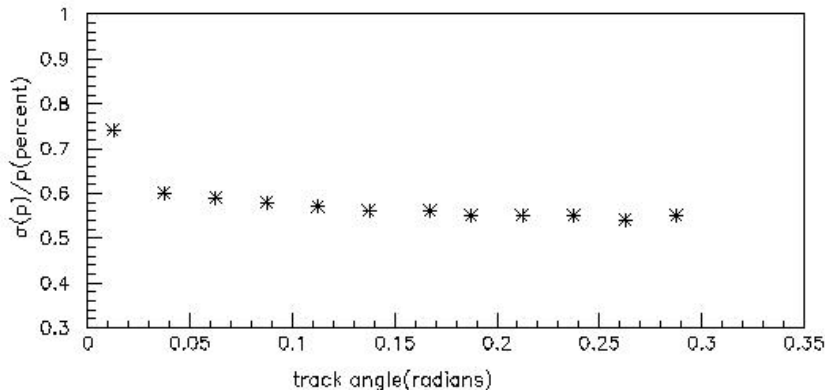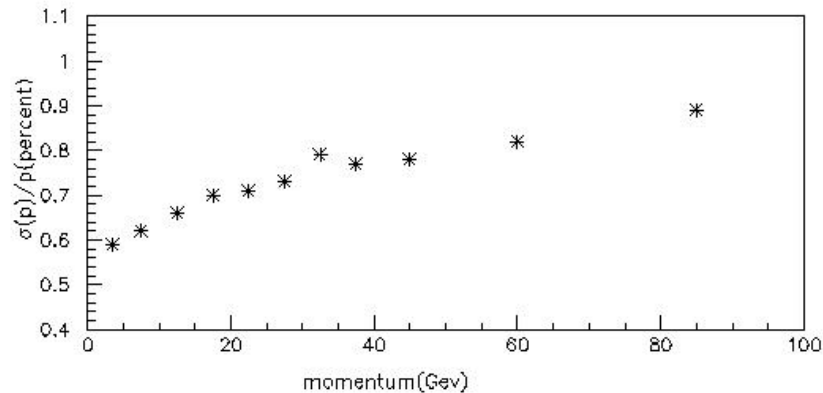
Predicted performance - Momentum resolution better than 1% over full momentum and angle range



Drawing Of forward Microstrip tracker

Ring Imaging Cherenkov Counter

- Original system had a gas radiator, C_4F_{10}, and an aerogel radiator, both detected on planes of Hybrid PhotoDiodes.
- The gas section has plenty of photons and is turning out to be straightforward to implement
- The aerogel was proven to be inadequate. It has too few photons distributed in large, diffuse rings which get tangled up in the more intense rings from the gas section. The thickness of the aerogel is limited by scattering by bubbles
- Without the aerogel, we lack K/p discrimination below 9 GeV, which especially impacts our "kaon" tagging performance
- We have replaced the aerogel with a liquid, C_5F_{12}, which makes more photons and at very large angles. These are detected on a new array of PMTs on the sides of the gas vessel. With more photons, and separated readout, the problems are solved
- The tubes are an added cost, (only) partially offset by now needing a smaller HPD array

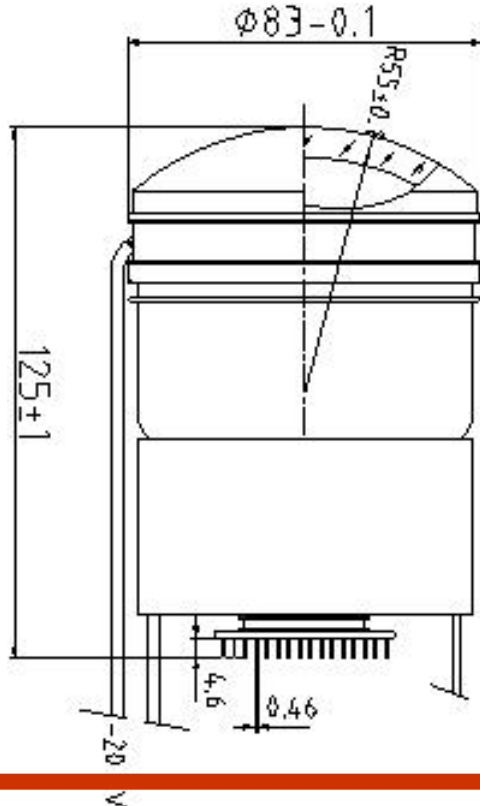# Layout of the New Particle Identifier showing the liquid radiator and its PMTs
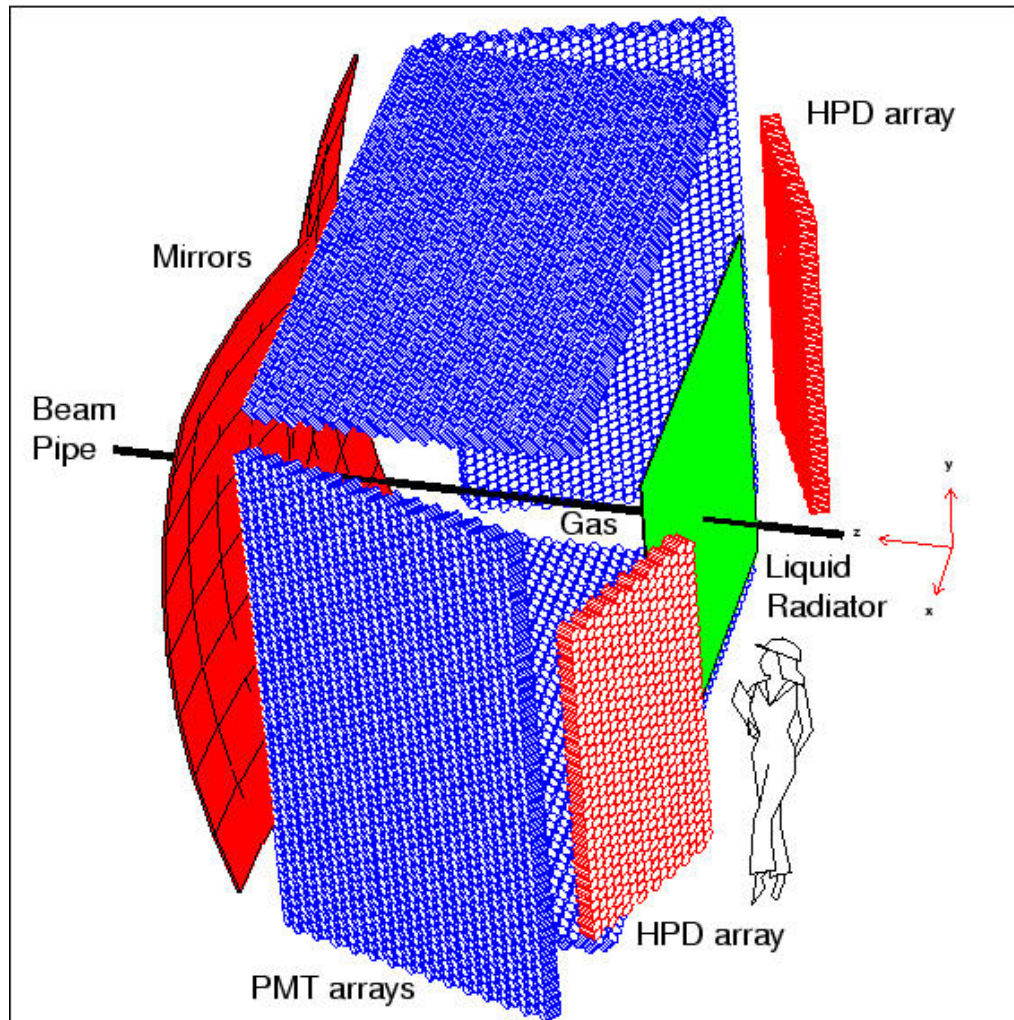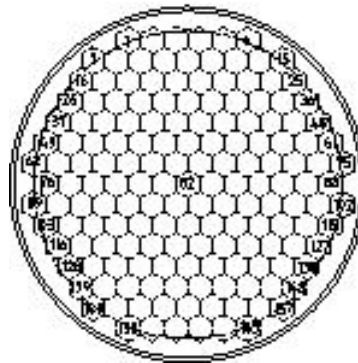

Cherenkov angle vs P
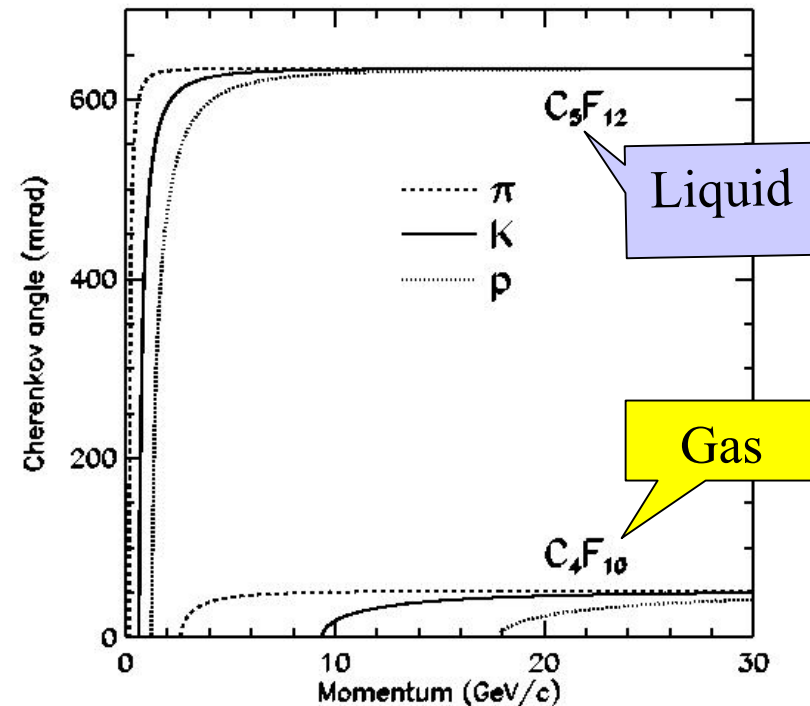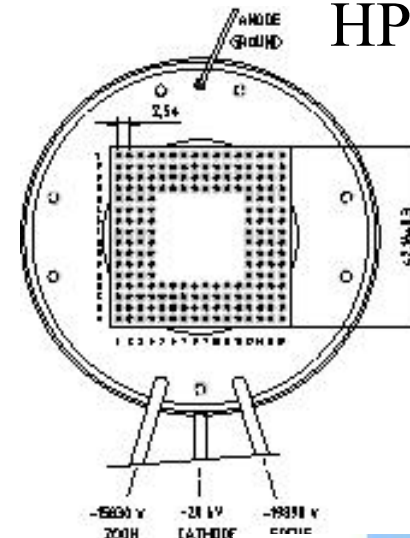
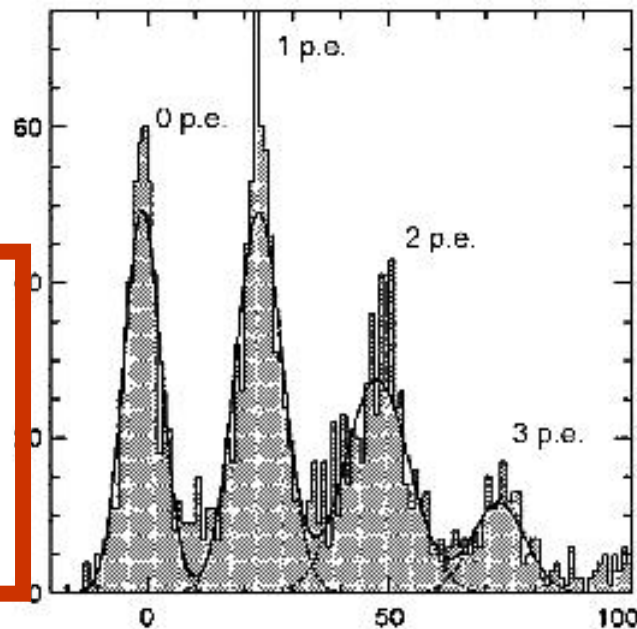# HPD Schematic/MAPMT option

HPD Tube

HPD Pixel array

HPD Pinout

**Pulse Height from 163 pixel prototype HPD. Note pedestal, 1, 2, 3 pe peaks**

Multi-anode PMT

1″ X 1″

0 p.e.

1 p.e.

2 p.e.

3 p.e.

Electromagnetic Calorimeter

Table 4.8: Properties of PbWO$_4$

Property	Value
Density (g/cm^3)	8.28
Radiation Length (cm)	0.89
Interaction Length (cm)	22.4
Light Decay Time (ns):	5(39%)
	15(60%)
	100(1%)
Refractive Index	2.30
Maximum of emission (nm)	440
Temperature Coefficient (%/°C)	-2
Light output/NaI(Tl) (%)	1.3
Light output (pe/MeV into a 2" PMT)	10

Table 4.9: Properties of the BTeV electromagnetic Calorimeter

Property	Value
transverse block size, back	28.0 mm × 28.0 mm
tapered, smaller in front	27.2 mm× 27.2 mm
Block length	22 cm
Radiation Lengths	25
Front end electronics	PMT
Digitization/readout	QIE (FNAL)
Inner Dimension	± 9.88 cm × ± 9.88 cm
Outer Radius	160 cm
Total blocks per arm	10500

Fit function $= a \oplus b/\sqrt{E} \oplus c/E$

$a = 0.33 \pm 0.02$ %
$b = 1.8 \pm 0.1$ %
$c = 2.4 \pm 0.2$ %
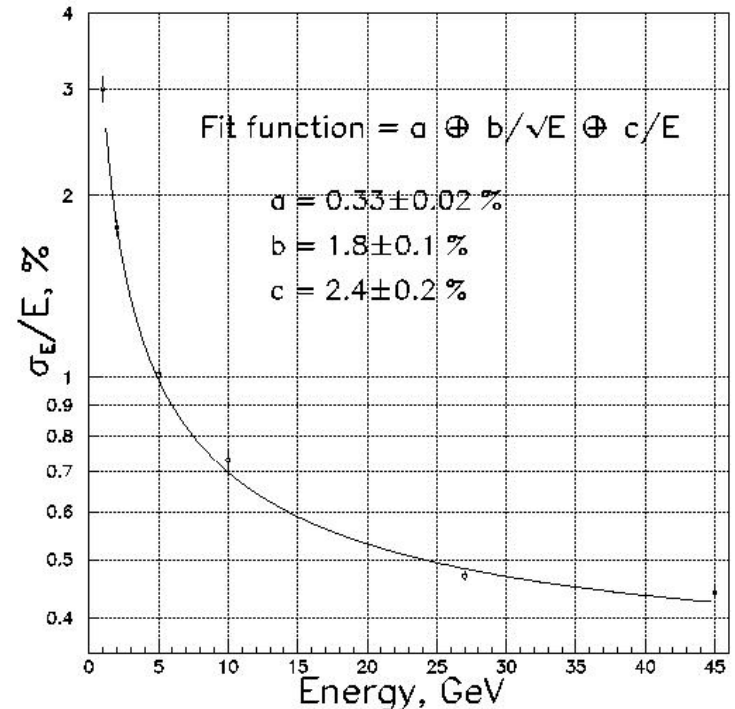
Resolution as measured in Test beam at IHEP/Protvino. Stochastic term = 1.8%

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Lead Tungstate Electromagnetic Calorimeter
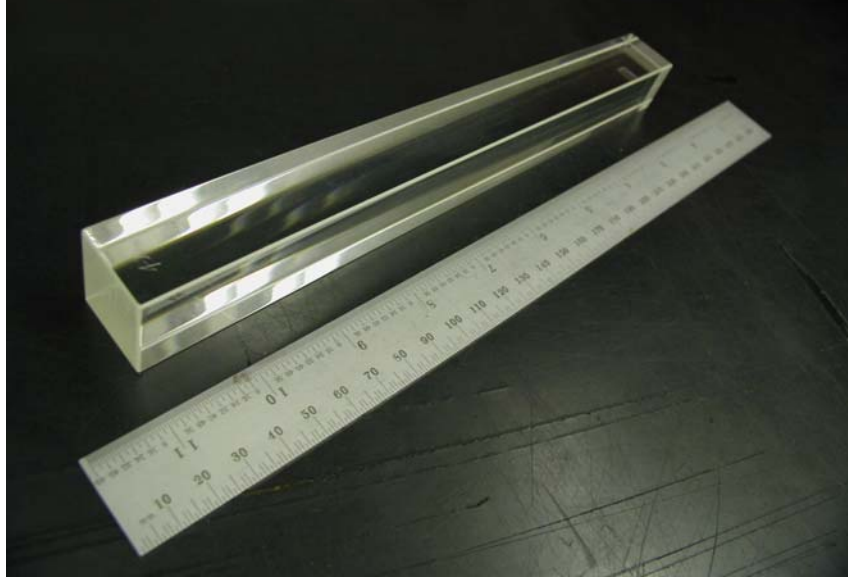
Block from China's Shanghai
Institute of Ceramics

5X5 stack of blocks from Bogoriditsk,
Russia ready for testing at Protvino in March

Lead Tungstate Crystals similar to CMS. Capable of excellent energy and spatial resolution. We will read them out with PHOTOMULTIPLIER tubes unlike CMS which uses avalanche photodiodes (and triodes for endcap) because of magnetic field. **This system can achieve CLEO/BaBar/BELLE-like performance in a hadron Collider environment!**
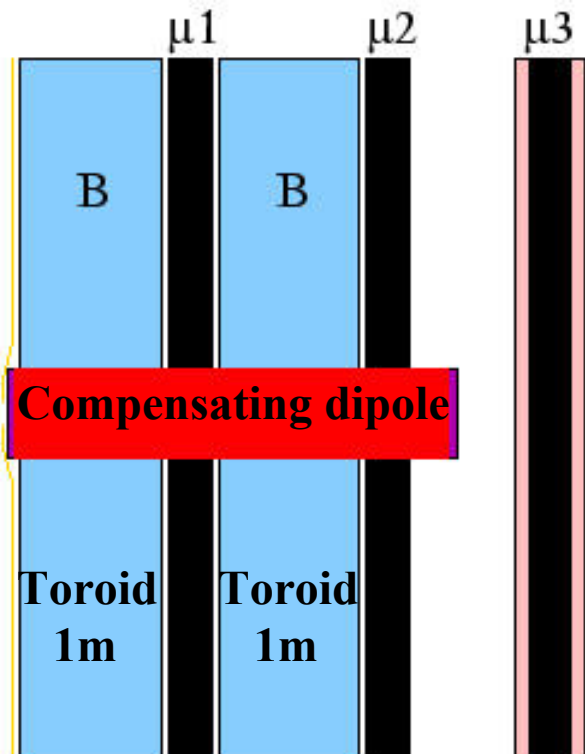
EMCAL Stand

Half-height prototype of EMCAL support. Crystals can be loaded in small groups or even individually. The final support can be installed on the beam very early.

Muon Detector

μ1   μ2   μ3

B   B

Compensating dipole

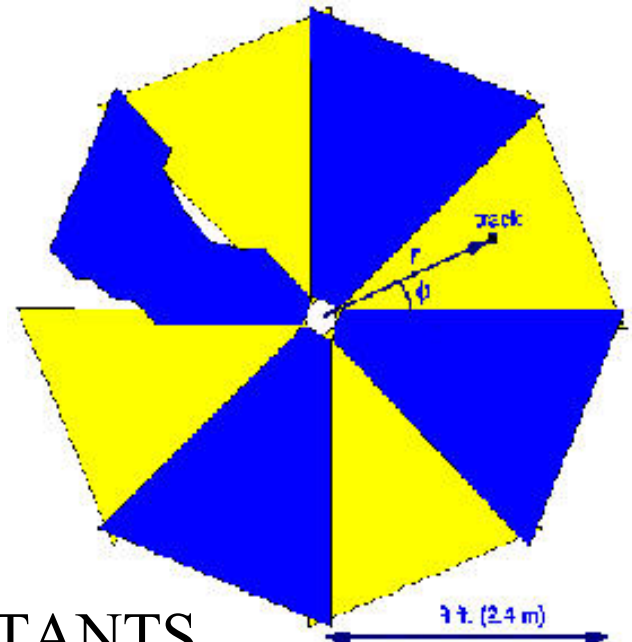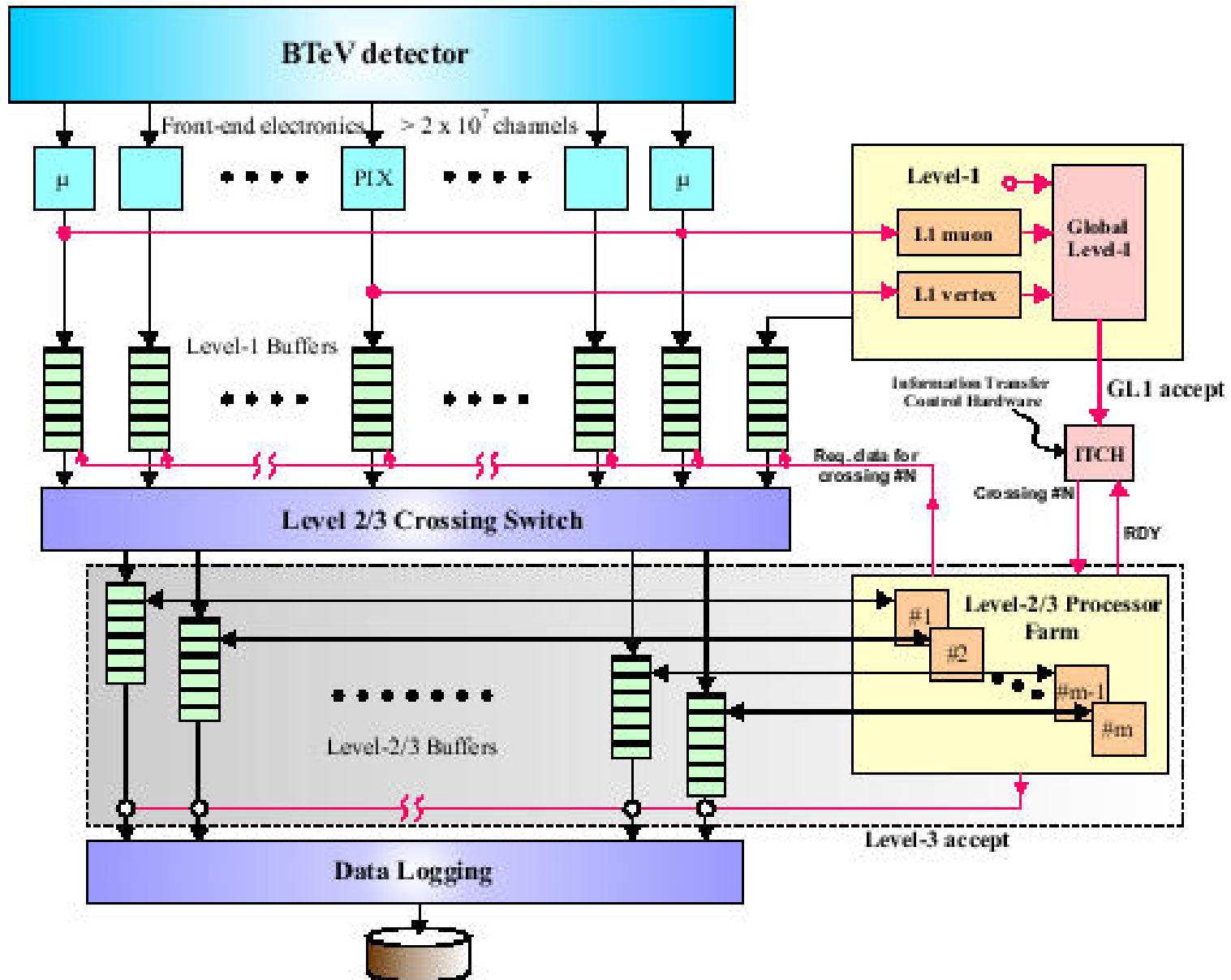**Toroid 1m**   **Toroid 1m**

PLANKS

VIEWS

OCTANTS

7 ft. (2.4 m)
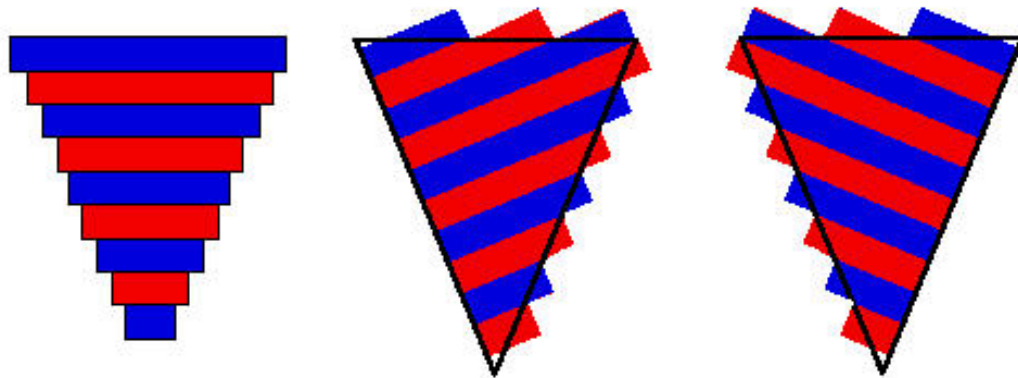
Muon Installation Mockup

Mockup of Muon Detector to understand how the Octants will be installed in the toroid steel in the C0 Hall

# Trigger

The BTeV Level I Vertex Trigger

The trigger will reconstruct every beam crossing and look for TOPOLOGICAL evidence of a B decaying downstream of the primary vertex. Runs at 7.6 MHz!

- **Key Points**
    - **This is made possible by a vertex detector with excellent spatial resolution, fast readout, low occupancy, and 3-d space points.**
    - **A heavily pipelined and parallel processing architecture using inexpensive processing nodes optimized for specific tasks ~ 2500 processors (DSPs).**
    - **Sufficient memory (~1 Terabyte) to buffer the event data while calculations are carried out.**
    - **Number of conventional processors in Level 2/3 Farm is 2000**

Result: Level 1 Trigger is about 60-70% efficient in accepting the events that are reconstructable and pass basic cuts,i.e. the events that would appear in publications, while rejecting 99% of the background.

Prototype DSP Level 1 DSP Board
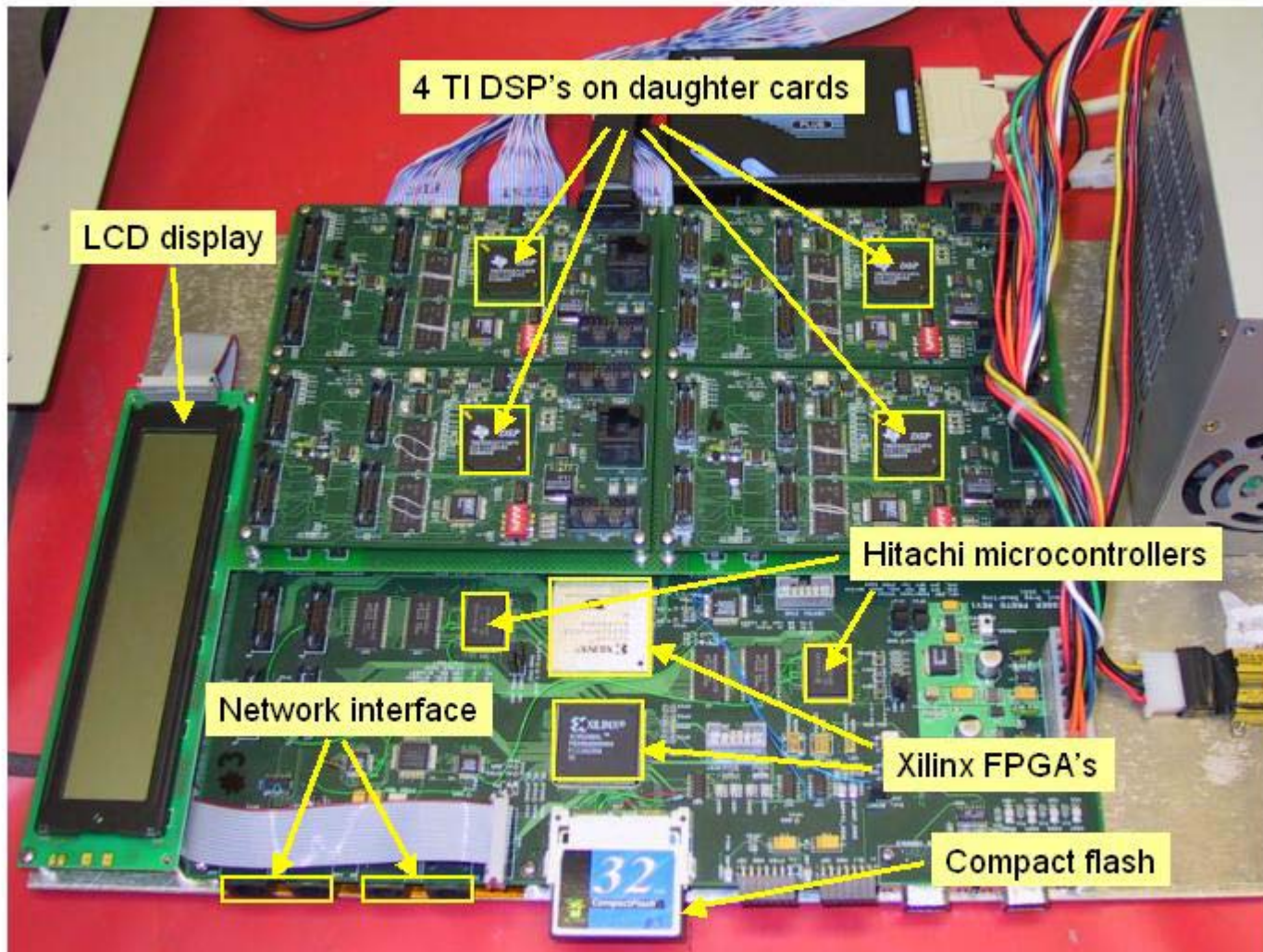
BTeV Cost Estimate and Schedule

- Cost estimate is derived from a complete, task-oriented WBS. Realistic assumptions are made about the production model. We have worked hard to include integration activities in a complete and consistent manner

- It includes cost and scheduling information. It is being uploaded into scheduling software (already) licensed from WELCOM (who also produces the COBRA interface to the labs financial and budgeting databases), which is called Open Plan.

- Along with a Web-based interface this give us a full project management system

- Estimate starts in FY2004, when we "hopefully" become a construction project. IT IS IN FY2002 DOLLARS.

- Includes contingency-- 37.5%

- Resource loaded schedule to be completed using OpenPlan by end of mid-summer

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Level 2 Cost Rollup

WBS #	WBS Activity Name	Construction (w.o. contingency) Million $ ('02)	Construction (with Contingency) Million $ ('02)
1	BTeV Construction	89.57	122.46
1.1	Vertex, Toroidal Magnet, Beam Pipe	1.34	1.88
1.2	Pixel Detector	11.80	17.08
1.3	RICH Detector	10.03	13.54
1.4	EM Calorimeter	11.30	14.51
1.5	Muon Detector	3.61	5.42
1.6	Forward Straw Tracker	5.93	8.36
1.7	Forward Silicon Microstrip Tracker	4.90	7.11
1.8	Trigger Electronics and Software	9.98	14.22
1.9	Event Readout and Controls	11.82	14.68
1.10	System Installation, Integration, etc	4.28	8.07
1.11	Project Management	6.46	7.43
	G&A estimate completion	8.14	10.18

Note: of the $78.1M base cost, 41% is labor, 59% is M&S. We estimate that inflation will result in a "then year" cost of $139 M

Will BTeV Be Timely? -- YES!

- The character of this physics is that it unfolds gradually as statistics accumulate over a few years. In the end small differences in the starting time can be overcome by a superior detector. We do not know when the LHC will actually start up. If we did start late w.r.t. LHCb, we have a sufficient advantage in some KEY states that we could rapidly catch up, e.g. 4X better in ρ-π.

- BTeV is designed so components can be installed on the fly a little at a time on collider down days. We can run low luminosity, 10^{30}, collisions at the end of stores. We can debug detectors on flux from a wire target in the beam halo when collisions are not available. **We can be commissioned before the final IR is complete, with much of the detector in place by 2007/8.**

- We assume that the moment when the transition to BTeV will be made no later than 2009, when BTeV will begin to take data at high luminosity

Comparison to e^+e^-

- **At Snowmass, the E2 Working Group established that a 10^{35} luminosity e^+e^- machine, the end point of upgrades to existing machines, had 1/10 the events as BTeV for B_d and B_u physics. BTeV is unrivalled for B_s or other B hadrons.**

- **It concluded that for e^+e^- to be competitive would require a machine capable of a luminosity of 10^{36}!! This would not be an upgrade of PEP II but a new machine. It would require a tremendous investment of accelerator physicists to design, do the R&D, build, and commission this machine**

- **BABAR would have to be completely rebuilt and much R&D would be needed to develop several high risk technologies. Machine & detector costs?**

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Comparison of a Single Arm BTeV with LHCb

Event Yields and Signal to Background for $B^o \rightarrow \rho\pi$

Mode	Branching Ratio	BTeV Yield	BTeV S/B	LHCb Yield	LHCb S/B
B^o->$\rho^{+/-}\pi^{-/+}$	2.8×10^{-5}	5400	4.1	2140	0.8
B^o->$\rho^o\pi^o$	0.5×10^{-5}	776	0.3	880 "naïve, No backgnd	<0.05 My estimate

- BTeV is a factor of 2.5 better in raw yield and a factor of 4 when background dilution is accounted for. Unclear whether LHCb can even do B^o->$\rho^o\pi^o$ due to poor signal to background , but again would be a factor of four worse in effective number of events. **LHCb cannot do as well on χ etc.**

- BTeV's superior trigger, based on the pixel detector, and DAQ make it more able to follow new paths that may open up as more is learned

Concluding Remarks

- BTeV will make critical contributions to our knowledge of CP Violation as attention turns from initial observations to the work of finding out if the Standard Model explanation is correct and complete.

- BTeV is not just doing Standard Model physics. It is sensitive enough to reveal new phenomena.

- BTeV makes excellent use of an existing DOMESTIC HEP facility in which there has and will have been a huge investment but doesn't overtax precious accelerator R&D resources

- The R&D projects are critical to developing the technologies that will make these experiments possible. The work will insure that they will succeed and will increase the likelihood that they can be done on schedule and on budget.

- Hopefully, BTeV will form a key part of a world class domestic flavor physics program after the LHC takes firm possession of the energy frontier